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# EFFECT OF GRAIN VELOCITY AND FLOW RATE UPON THE PERFORMANCE OF A DIVERTER-TYPE SAMPLER

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# Effect of Grain Velocity and Flow Rate Upon the Performance of a Diverter-type Sampler

by

Harold A. Kramer, agricultural engineer
Market Quality Research Division
Agricultural Research Service

## SUMMARY

A fragile (low moisture) corn lot and a "tough" wheat lot (13.5 percent moisture content) containing screenings were sampled after free falls of 1 foot, 50 feet, and 80 feet by three identical diverter-type samplers.

Increased velocity, because of free fall, caused mechanical damage to the corn samples, but not to the wheat samples. When corn entered the diverters at a high velocity--as happened when the diverters were 50 and 80 feet below the discharge point of the corn--a significant amount of breakage occurred. The amount of broken corn in the samples, because of impact against the diverter, was greater than the amount in the overall lot. Consequently, the samples of corn drawn after 50 and 80 feet of fall caused overestimates of broken corn in the lot.

The velocity at which wheat and screenings entered the diverters did not appear to influence the accuracy of estimates based on samples drawn from the wheat lot.

Flow rate of the corn and wheat did not significantly affect accuracy of the samples, but during full flow the ratios of sample weight to flow rate were significantly lower for the upper sampler than for the middle and lower samplers.

## INTRODUCTION

Choice of a location for the installation of a diverter-type sampler is limited in many elevators by the space available or the arrangement of the conveying system, or both. Universal adoption of diverter-type samplers would be restricted if installations could only be approved for certain specified locations that many elevators could not meet. No reliable information was available on how grain velocity within a diverter-type sampler would influence--

1. Mechanical damage to the sample,
2. Size of the sample,
3. Accuracy and variability of the sample,
4. Service life of the sampler.

The purpose of this research was to answer the first three of these questions and to provide information that could be used as guidelines for the installation of diverter-type samplers.

The Dean Gamet Manufacturing Company provided three diverter-type grain samplers of identical construction. Cargill, Inc., provided grain, facilities for dropping the grain, bins, conveying equipment, sieving devices, scales, utilities, and experienced labor. The Minneapolis Laboratory of the Grain Division, Consumer and Marketing Service, U.S. Department of Agriculture, analyzed all the samples. The Market Quality Research Division and Biometrical Services Staff of the Agricultural Research Service provided the personnel required to plan, coordinate, and supervise the research and to tabulate, evaluate, and interpret the results.

# PROCEDURE

Figure 1 shows the general arrangement of the facilities used for this research. Three diverter-type samplers of the same model were located along a round 8-inch-diameter vertical spout. The samplers were as nearly identical in dimensions as manufacturing tolerances would permit. The diverters were driven by electric motors and gear reducers to insure that each would have a constant and equal velocity while traversing the grain stream. This was required to assure that differences found in corresponding increment samples[1] drawn by the three samplers could be attributed to grain velocity differences. The diverter velocities were 100 feet per minute and their slot widths were 0.75 inch.

The upper, middle, and lower samplers were located immediately below, 50 feet below, and 80 feet below, respectively, the calibrated gate of the 350-bushel-capacity hopper bin. Grain discharged from the hopper bin dropped approximately 100 feet to a flat concrete floor. The grain was reelevated by a pneumatic conveyor and elevator leg No. 6 (fig. 1) for additional cycles of sampling.

In the first phase of this research, fragile corn (rapidly dried to a low moisture content) was sieved to remove extraneous material and damaged kernels. Fragile corn was chosen so that sufficient kernels would break to provide measure of the mechanical damage to a sample caused by impact against a diverter. Twenty thousand pounds of this sieved, fragile corn was elevated to the hopper bin shown in figure 1. This corn was discharged from the hopper bin at two different flow rates by opening the calibrated gate to full or one-half flow position. The one-half flow position was determined during preliminary investigations. The two flow rates allowed a comparison of diverter performance under a range of grain flows normally experienced in a grain elevator.

Each of the three samplers was programed by random selection to draw increment samples at 15-second intervals during cycles 1, 3, and 6 and at 30-second intervals during cycles 2, 4, and 5. The 15-second interval was used during cycles of full flow and the 30-second interval during cycles of one-half flow. Thus, the quantity of grain represented by each increment sample was the same for each flow rate.

The sampling sequence was controlled with a cam-type electrical timer to insure simultaneous sampling for essentially the same portion of the grain stream by each diverter without interference between diverters. Each increment sample was collected in a separate plastic bag and identified as to cycle, sampler, and sample sequence.

The repeated handling of the fragile corn caused a considerable increase in broken kernels. After the sixth cycle, sampling was discontinued, the entire lot was separated into whole kernel corn and broken corn (using a 12/64-inch round-hole sieve), and the separate portions were weighed. These weights were--

| | Pounds | Percent |
|---|---|---|
| Whole kernel corn | 16,460 | 84.1 |
| Broken corn | 3,114 | 15.9 |
| Total | 19,574 | 100.0 |

In the second phase of this research, "tough" wheat (moisture content in excess of 13.5 percent) was sieved to remove extraneous material and broken kernels. An 18,000-pound quantity of the whole kernel wheat was placed in the hopper scale shown in figure 1. Screenings (weed seeds normally found in wheat) were sieved to remove fine particles and dust. A 2,000-pound quantity of the sieved screenings was layered on top of the wheat. This type of lot ("tough" wheat and screenings) was selected to determine if estimates based on samples drawn from the lot would be biased because of grain velocity and flow rate differences. The tough wheat would receive minimum mechanical damage during sampling and handling, and the known percentage

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[1] An increment sample is defined as the sample drawn during one traverse of a diverter through the grain stream.

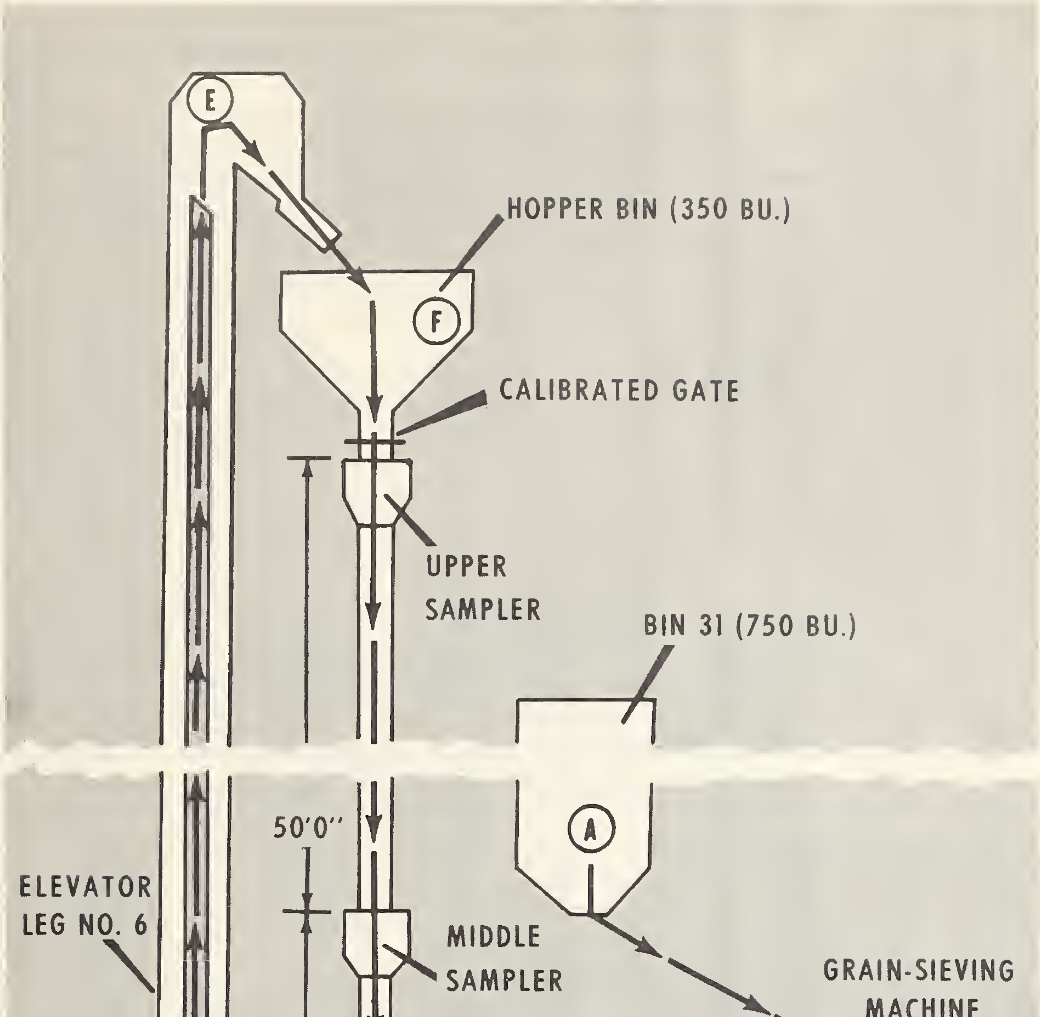

Figure 1.--Layout of the grain sampling and handling facility and the flow pattern used for each sampling cycle.

of screenings in the lot would serve as a base to measure bias because of velocity and flow rate differences. The 20,000-pound wheat lot was transferred from the hopper scale to the hopper bin by elevator leg No. 6.

The procedure followed for sampling and cycling the wheat lot was the same as for the corn lot, but the number of cycles was increased to 10. Cycles 1, 3, 5, 8, and 10 were at full flow rate and 15-second sampling interval, and cycles 2, 4, 6, 7, and 9 were at one-half flow rate and 30-second sampling interval. After cycle 10, the entire lot was separated into wheat and screenings and the separate portions were weighed. These weights were--

| | Pounds | Percent |
|---|---|---|
| Wheat | 17,577 | 90.6 |
| Screenings | 1,828 | 9.4 |
| Total | 19,405 | 100.0 |

TABLE 1.--Average weight, composition, and standard deviation of corn samples by cycle, sampler location, and sampling interval

| Cycle and sampler position | Lot weight | Flow rate | Duration of grain flow | Sampling interval | Increment samples[1] | Sample weight | | Ratio--sample weight to flow rate | Broken corn in sample | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Weight[2] | Standard deviation | | Percentage of sample | Standard deviation |
| | Lb. | Lb./min. | Min. | Sec. | No. | G. | G. | | Pct. | Pct. |
| CYCLE 1 | | | | | | | | | | |
| Upper | 20,000 | 3,771 | 5.32 | 15 | 21 | 570 | 16.1 | 0.15 | 0.25 | 0.09 |
| Middle | 20,000 | 3,771 | 5.32 | 15 | 21 | 984 | 45.5 | .26 | 2.12 | .17 |
| Lower | 20,000 | 3,771 | 5.32 | 15 | 21 | 994 | 53.6 | .26 | 4.26 | .21 |
| CYCLE 2 | | | | | | | | | | |
| Upper | 19,939 | 1,754 | 11.37 | 30 | 22 | 373 | 14.3 | .21 | 2.05 | .53 |
| Middle | 19,939 | 1,754 | 11.37 | 30 | 22 | 459 | 17.1 | .26 | 3.95 | .51 |
| Lower | 19,939 | 1,754 | 11.37 | 30 | 22 | 444 | 25.8 | .25 | 6.04 | .53 |
| CYCLE 3 | | | | | | | | | | |
| Upper | 19,878 | 4,158 | 4.78 | 15 | 18 | 670 | 9.2 | .16 | 4.83 | .90 |
| Middle | 19,878 | 4,158 | 4.78 | 15 | 18 | 1,002 | 57.9 | .24 | 7.72 | .90 |
| Lower | 19,878 | 4,158 | 4.78 | 15 | 18 | 1,085 | 38.2 | .26 | 10.09 | .91 |
| CYCLE 4 | | | | | | | | | | |
| Upper | 19,817 | 2,060 | 9.62 | 30 | 18 | 429 | 17.2 | .21 | 7.24 | 1.60 |
| Middle | 19,817 | 2,060 | 9.62 | 30 | 18 | 540 | 35.7 | .26 | 9.05 | 1.48 |
| Lower | 19,817 | 2,060 | 9.62 | 30 | 18 | 530 | 21.8 | .26 | 11.56 | 1.58 |
| CYCLE 5 | | | | | | | | | | |
| Upper | 19,757 | 2,054 | 9.62 | 30 | 19 | 426 | 8.4 | .21 | 10.01 | 3.06 |
| Middle | 19,757 | 2,054 | 9.62 | 30 | 19 | 524 | 18.5 | .26 | 11.86 | 2.68 |
| Lower | 19,757 | 2,054 | 9.62 | 30 | 19 | 529 | 23.9 | .26 | 15.08 | 3.49 |
| CYCLE 6 | | | | | | | | | | |
| Upper | 19,696 | 4,129 | 4.77 | 15 | 19 | 680 | 16.4 | .16 | 13.51 | 4.06 |
| Middle | 19,696 | 4,129 | 4.77 | 15 | 19 | 986 | 95.6 | .24 | 15.50 | 4.34 |
| Lower | 19.696 | 4,129 | 4.77 | 15 | 19 | 1,047 | 41.2 | .25 | 17.46 | 3.42 |

[1] Increment samples drawn by the sampler during grain flow.

[2] Average weight of the samples drawn.

# RESULTS AND DISCUSSION

## CORN LOT

Data obtained from six cycles of sampling of corn are tabulated in table 1 and are summarized in tables 2 and 3 and in figure 2. Table 1 and figure 2 show that the percentage of broken kernels in the lot increased appreciably during each cycle and from cycle to cycle. This increase was expected because of the fragile corn used, the impact after the corn dropped 100 feet to the concrete floor, and the breakage that occurred during each reelevation to the hopper bin. Since samples drawn during the sixth cycle indicated that broken kernels were in excess of 13 percent, further cycling was terminated.

The data in table 1 and figure 2 show that in cycle 1 the sample drawn by the upper sampler contained 0.25 percent broken corn. This sample appears to be representative as the entire lot had been sieved to remove broken corn. The percentages of broken corn in samples drawn by the upper sampler increased to 13.51 in cycle 6. After cycle 6 the entire lot was elevated from the basement floor and sieved. Broken corn removed from the lot was 15.90 percent of the total lot. Agreement between lot and sample percentages at beginning and end of cycling and the consistent increase in broken corn indicate the samples drawn by the upper sampler were representative of the lot.

Samples drawn by the middle sampler contained, on the average, about 1.99 percent more broken corn than samples drawn by the upper sampler. Samples drawn by the lower sampler averaged about 4.44 percent more broken corn. The magnitude and the consistency of these increases indicate these differences are real and that samples drawn by the middle and lower samplers were not representative of the lot but contained an excess of broken corn caused by impact of the corn against the diverter. Also, the ratio of broken corn found by the lower sampler to that found by the middle sampler agrees well with the increase in impact energy (against the diverters) that would be expected because of greater corn velocity at the lower sampler position. A decrease in the flow rate from full to one-half had no appreciable effect upon percentage of broken kernels found in the samples.

Therefore, one might conclude that if samplers are installed 50 feet or more below an elevator head or bin discharge gate, the samples drawn may cause an over-estimate of the amount of broken kernels in the lot. This would be true especially if the grain was fragile and subject to breaking. Additional research is needed to determine the minimum distance fragile corn can drop in free fall before a significant increase in broken kernels would occur because of impact against a sample diverter.

Data in tables 1 and 3 show how the flow rate and the velocity of the corn at the upper, middle, and lower sampler positions influenced the weight of samples drawn by the diverter during one traverse of the corn stream. The sample weight to flow rate ratios for samples drawn at full flow and one-half flow rates are nearly the same except for the upper sampler, which drew a significantly smaller sample than the other samplers at full flow rate. There was visual indication that at full flow rate the diverter in the upper position, overflowed while traversing the corn stream. A diverter would overflow if free flow of corn through it was restricted because of its limited capacity. Corn velocity increased as the corn dropped; this increase in velocity and the corresponding, decrease in cross-section area of the grain stream may explain why the middle and the lower samplers drew the larger samples. The largest increase in sample weight occurred between the upper and middle samplers where the corn dropped 50 feet. A smaller increase occurred between the middle and lower samplers where the additional drop was 30 feet. Additional research using high speed photography is needed to confirm what occurs.

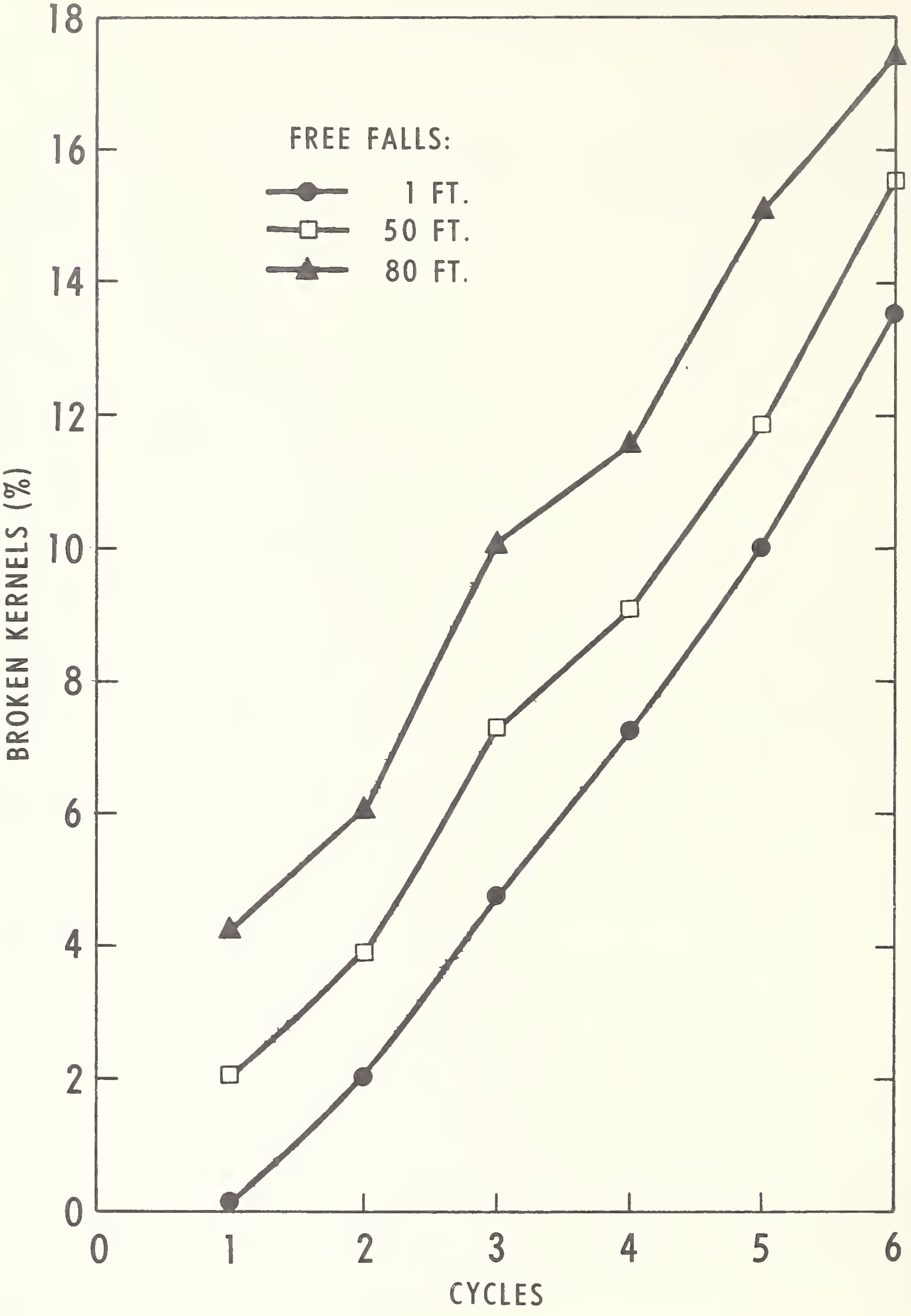

Figure 2.--Percentages of broken kernels in samples of corn drawn by upper, middle, and lower samplers during six cycles of handling of the grain.

TABLE 2.--Percentage of broken kernels in corn samples as influenced by position of the samplers and flow rate of the corn[1]

| Sampler position | Flow rate[2] | |
|---|---|---|
| | Full | One-half |
| | Percent | Percent |
| Upper............ | 6.2 a | 6.4 a |
| Middle............ | 8.2 a b | 8.2 a b |
| Lower............ | 10.5 b | 10.8 b |
| Average......... | 8.3 | 8.5 |

[1] Data are percentages of broken kernels in the first 18 subsamples from 3 cycles of each flow rate.

[2] Numbers followed by different letters in same column are significantly different at the 5-percent level.

TABLE 3.--Weight of corn samples as influenced by position of the samplers and flow rate of the corn[1]

| Sampler position | Flow rate[2] | |
|---|---|---|
| | Full | One-half |
| | Grams | Grams |
| Upper.............. | 641 a | 409 a |
| Middle.............. | 993 b | 509 a |
| Lower.............. | 1,042 b | 503 a |
| Average.......... | 892 | 474 |

[1] Data are average weights of the first 18 subsamples from 3 cycles of each flow rate.

[2] Numbers followed by different letters in the same column are significantly different at the 5-percent level.

## WHEAT LOT

Data obtained from 10 cycles of sampling are tabulated in table 4 and are summarized in tables 5 and 6 and figure 3. Table 4 and figure 3 show a gradual decrease in the percentage of screenings found in samples drawn during cycles 1 to 10. This decrease agrees with a loss of screenings for the lot. The wheat lot, as prepared, contained 10 percent screenings. Separation of the screenings from the wheat after 10 cycles of sampling showed that the lot contained 9.4 percent screenings. The 0.6 percent loss is attributed to handling and is assumed to be a straight line loss. The assumed percentage of screenings in the lot is shown by a broken line in figure 3.

The data in table 5 and figure 3 show that neither velocity, sampler position, nor flow rate of the wheat lot influenced the percentage of screenings drawn by the diverters. The small differences indicated in table 5 are not statistically significant.

The data in tables 4 and 6 show how velocity and flow rate of the wheat influenced the weight of samples drawn by the diverters during one traverse of the wheat stream. These data are similar to the corn data in tables 1 and 3.

TABLE 4.--Weight and composition of wheat samples by cycle, sampler position, and sampling interval

| Cycle and sampler position | Lot weight | Flow rate | Duration of grain flow | Sampling interval | Increment samples[1] | Sample weight |  | Ratio--sample weight to flow rate | Screenings in sample |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  | Weight[2] | Standard deviation |  | Percentage of sample | Standard deviation |
|  | Lb. | Lb./min. | Min. | Sec. | No. | G. | G. |  | Pct. | Pct. |
| CYCLE 1 |  |  |  |  |  |  |  |  |  |  |
| Upper........ | 20,000 | 5,063 | 3.95 | 15 | 15 | 1,100 | 11.7 | 0.22 | 10.89 | 6.17 |
| Middle....... | 20,000 | 5,063 | 3.95 | 15 | 15 | 1,272 | 59.3 | .25 | 10.23 | 6.13 |
| Lower........ | 20,000 | 5,063 | 3.95 | 15 | 15 | 1,321 | 68.5 | .26 | 9.23 | 5.28 |
| CYCLE 2 |  |  |  |  |  |  |  |  |  |  |
| Upper........ | 19,946 | 2,649 | 7.53 | 30 | 15 | 658 | 23.5 | .25 | 12.04 | 7.68 |
| Middle....... | 19,946 | 2,649 | 7.53 | 30 | 15 | 729 | 57.8 | .28 | 10.84 | 4.88 |
| Lower........ | 19,946 | 2,649 | 7.53 | 30 | 15 | 723 | 58.7 | .27 | 9.92 | 3.01 |
| CYCLE 3 |  |  |  |  |  |  |  |  |  |  |
| Upper........ | 19,892 | 4,948 | 4.02 | 15 | 16 | 1,043 | 7.3 | .21 | 10.27 | 2.17 |
| Middle....... | 19,892 | 4,948 | 4.02 | 15 | 16 | 1,207 | 59.7 | .24 | 9.98 | 2.27 |
| Lower........ | 19,892 | 4,948 | 4.02 | 15 | 16 | 1,273 | 85.1 | .26 | 9.82 | 2.33 |
| CYCLE 4 |  |  |  |  |  |  |  |  |  |  |
| Upper........ | 19,838 | 2,652 | 7.48 | 30 | 15 | 639 | 11.3 | .24 | 9.68 | 2.45 |
| Middle....... | 19,838 | 2,652 | 7.48 | 30 | 15 | 701 | 40.5 | .26 | 9.26 | 2.27 |
| Lower........ | 19,838 | 2,652 | 7.48 | 30 | 15 | 720 | 47.8 | .27 | 9.37 | 2.24 |
| CYCLE 5 |  |  |  |  |  |  |  |  |  |  |
| Upper........ | 19,784 | 4,909 | 4.03 | 15 | 16 | 1,022 | 10.8 | .21 | 9.52 | 2.77 |
| Middle....... | 19,784 | 4,909 | 4.03 | 15 | 16 | 1,178 | 62.5 | .24 | 9.44 | 2.57 |
| Lower........ | 19,784 | 4,909 | 4.03 | 15 | 16 | 1,225 | 61.3 | .25 | 9.41 | 2.95 |
| CYCLE 6 |  |  |  |  |  |  |  |  |  |  |
| Upper........ | 19,730 | 2,613 | 7.55 | 30 | 15 | 638 | 18.8 | .24 | 10.09 | 3.66 |
| Middle....... | 19,730 | 2,613 | 7.55 | 30 | 15 | 705 | 31.5 | .27 | 9.42 | 3.08 |
| Lower........ | 19,730 | 2,613 | 7.55 | 30 | 15 | 687 | 39.1 | .26 | 9.47 | 3.18 |
| CYCLE 7 |  |  |  |  |  |  |  |  |  |  |
| Upper........ | 19,621 | 2,606 | 7.53 | 30 | 14 | 627 | 10.6 | 0.24 | 9.47 | 2.75 |
| Middle....... | 19,621 | 2,606 | 7.53 | 30 | 14 | 697 | 37.7 | .27 | 9.44 | 2.59 |
| Lower........ | 19,621 | 2,606 | 7.53 | 30 | 14 | 672 | 32.5 | .26 | 9.57 | 2.99 |
| CYCLE 8 |  |  |  |  |  |  |  |  |  |  |
| Upper........ | 19,675 | 4,919 | 4.00 | 15 | 16 | 1,015 | 12.2 | .21 | 9.34 | 3.68 |
| Middle....... | 19,675 | 4,919 | 4.00 | 15 | 16 | 1,188 | 47.4 | .24 | 9.12 | 3.55 |
| Lower........ | 19,675 | 4,919 | 4.00 | 15 | 16 | 1,266 | 114.9 | .26 | 9.84 | 3.68 |
| CYCLE 9 |  |  |  |  |  |  |  |  |  |  |
| Upper........ | 19,513 | 2,602 | 7.50 | 30 | 14 | 631 | 11.1 | .24 | 9.51 | 3.21 |
| Middle....... | 19,513 | 2,602 | 7.50 | 30 | 14 | 691 | 48.5 | .27 | 8.93 | 3.15 |
| Lower........ | 19,513 | 2,602 | 7.50 | 30 | 14 | 681 | 41.1 | .26 | 8.44 | 3.07 |
| CYCLE 10 |  |  |  |  |  |  |  |  |  |  |
| Upper........ | 19,567 | 4,892 | 4.00 | 15 | 16 | 1,008 | 10.6 | .21 | 9.17 | 3.87 |
| Middle....... | 19,567 | 4,892 | 4.00 | 15 | 16 | 1,172 | 57.6 | .24 | 9.56 | 4.14 |
| Lower........ | 19,567 | 4,892 | 4.00 | 15 | 16 | 1,254 | 67.9 | .26 | 9.35 | 3.93 |

[1] Increment samples drawn by the sampler during the grain flow.
[2] Average weight of the samples drawn.

TABLE 5.--Percentage of screenings in wheat samples as influenced by position of the samplers and flow rates of the wheat[1]

| Sampler position | Flow rate[2] | |
|---|---|---|
| | Full | One-half |
| | Percent | Percent |
| Upper.............. | 10.2 | 10.0 |
| Middle............. | 10.0 | 9.7 |
| Lower.............. | 9.8 | 9.6 |
| Average.......... | 10.0 | 9.8 |

[1] Data are average percentages of screenings in the first 13 subsamples from 5 cycles of each flow rate.

[2] None of the differences were significant at the 5-percent level.

TABLE 6.--Weight of wheat samples as influenced by position of the samplers and flow rates of the wheat[1]

| Sampler position | Flow rate[2] | |
|---|---|---|
| | Full | One-half |
| | Grams | Grams |
| Upper.............. | 1,038 a | 637 a |
| Middle............. | 1,206 b | 702 a |
| Lower.............. | 1,265 b | 695 a |
| Average.......... | 1,170 | 678 |

[1] Data are average weights of the first 13 subsamples from 5 cycles of each flow rate.

[2] Numbers followed by different letters in same column are significantly different at the 5-percent level.

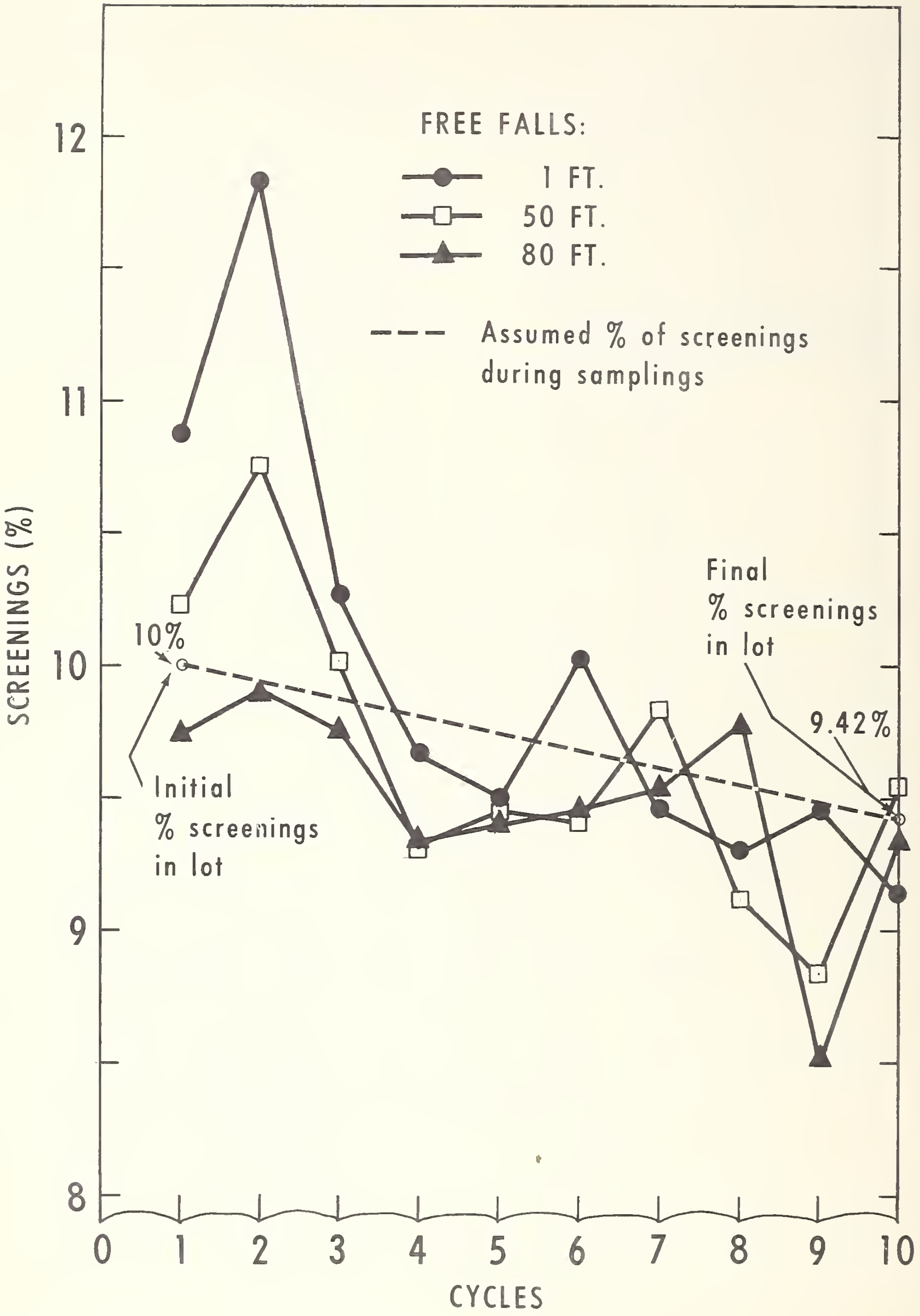

Figure 3.--Percentages of screenings in samples of wheat drawn by upper, middle, and lower samplers during 10 cycles of handling of the grain.